research review

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Laser Plasma Probe

LOUIS C. BLOCK, Optical Physics Laboratory, AFCRL

A highly precise laser plasma diagnostic probe has been developed by General Electric (Syracuse) under AFCRL contract. The device shows promise as an in-flight instrument to measure the electron-density distribution in the flow field of a re-entering hypersonic vehicle. It also measures the electron temperature of the plasma at the same point simultaneously.

It does this with high resolution in portions of the flow field of interest. It does not disrupt or modify the flow field, and it has application to other plasma diagnostic requirements.

A ruby laser is used to transmit a small (1/2-inch diameter) beam of monochromatic light through the plasma. At a point of interest along this beam, a spectrometer and sensitive photomultiplier tube are used to detect and observe the Doppler broadened, scattered energy. These observations are then recorded on photographic film by means of an oscilloscope and camera.

The need for an improved plasma diagnostic probe has been recognized for some time. Devices such as the classical Langmuir probe or microwave interferometer have certain deficiencies of undesirable effects when used to measure electron densities or temperature in a plasma. The Langmuir probe sets up a shock wave of its own, or might burn off in a hypersonic flow field. Microwave interferometers lack resolution and are generally impractical for in-flight use since it is necessary to have access to both sides of the plasma being measured. For nonuniform plasmas, the interferometer technique can only infer what the average electron density may be, without providing details on the variation of plasma parameters with distance.

The ruby-laser plasma probe can measure the electron-density distribution with a resolution of 1 cm^3 or even less (perhaps as small as a lens system can provide by focusing down a high-power ruby-laser beam.) It utilizes a 0.30 joule, Q-Spoiled laser with a 1cm diameter beam and a pulse duration of 30 nanoseconds.

The highly promising probe is still under laboratory test; development has not yet reached the point of implementation.

research review
OFFICE OF AEROSPACE RESEARCH

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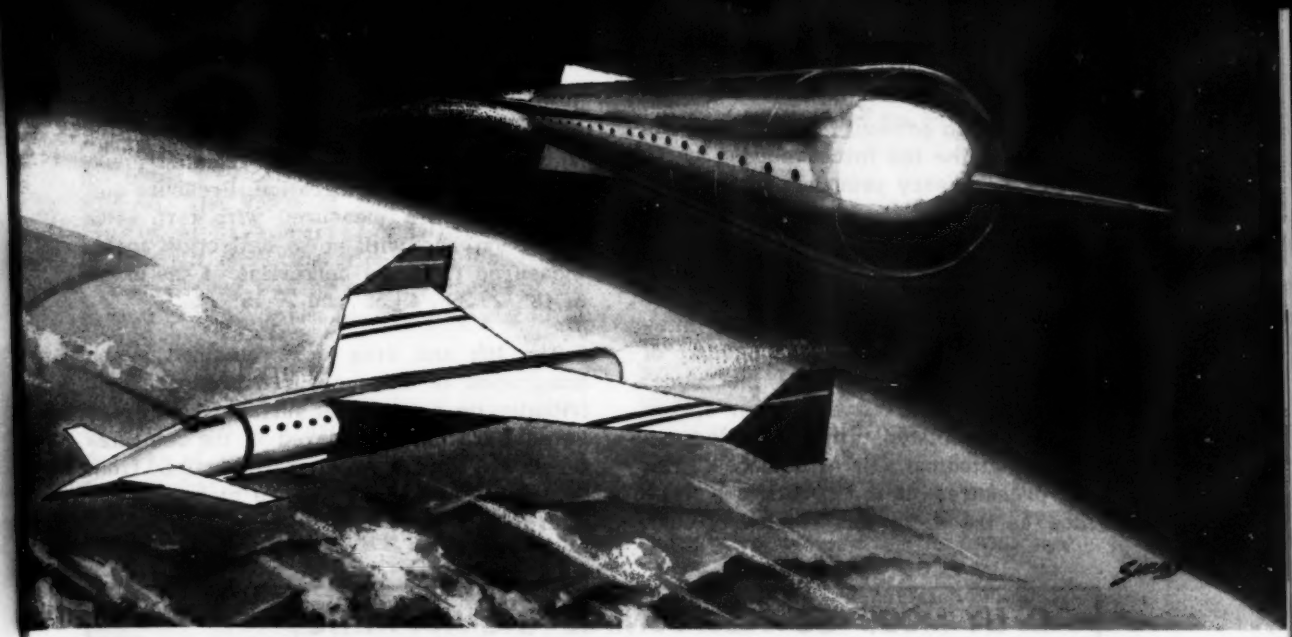
From the Editor:

This issue marks the third appearance of the Review with its new format. We have been gratified by the favorable comments received thus far. We would, however, like to hear from our many readers throughout the government and scientific community, whether pro or con. We are always open to suggestions that will help us achieve the objective of the Review, which is to accelerate the exchange of information concerning Air Force conducted and sponsored research activities.

JACOB SEIDEN
Editor



flow-separation spikes as hypersonic control devices

CAPTAIN WILLIAM E. THURMAN, Hypersonic Research Laboratory, ARL

The idea of controlling a high-speed vehicle traveling in the atmosphere with a thin spike protruding ahead of the vehicle is reminiscent of science fiction. However, this fiction may soon become a reality since the adaptability of a spike as an attitude control for launch vehicles will be investigated by Rocketdyne Division of North American Aviation under a contract from the U. S. A. F. Flight Test Center (Aviation Week - 20 January 1964).

There is a body of empirical data compiled in a number of research laboratories which supports the selection of a spike for a control device. Numerous investigators have shown that the flow over a body is radically changed by the addition of a spike. They have shown that the form drag caused by the pressure acting on the forebody is reduced by the spike and, if the flow remains laminar (turbulence free), the over-all heat-transfer rate to the body nose is also reduced. The spike serves to separate the flow so that the nose of the body does not experience the high pressures and temperatures of a blunt high-speed body. It was this significant change in the flow over the body caused by the flow-separation spike which suggested that the spike might have application as a control device for re-entry or high-speed flight.

The magnitude of the forces which could result from a flow-separation spike deflection was measured for the first time in a study conducted in the Aerospace Research Laboratories' 3-inch hypersonic wind tunnel. The study was completed and the results have been published as an AIAA Journal Note. This study was also reported in Aviation Week, 28 October 1963. The tests were made at Mach 12 and at a Reynolds number of 28,700/inch and gave an initial estimate of the control effectiveness which resulted from a deflected flow-separation spike mounted ahead of the body.

The model tested was axisymmetric and consisted of a right circular-cylindrical afterbody, 1/2 inch in diameter, with a hemispherical nose. A flow-separation spike, 2 inches long, extended ahead of the body. Tests by other investigators had shown that this spike length was optimum for reducing the drag and lowering the heat-transfer rate to the body.

A balance system sensitive enough to measure the very small forces involved was

not available, so pressure integration was used to determine the forces caused by the spike. The necessary pressure distribution was obtained from 10 pressure orifices located at various spiral positions about the model surface. This was the maximum number of orifices that could be placed in the model. However, accurate pressure integration required a much larger number of pressure readings. Therefore, the model was designed with fixed deflection spikes which could be rotated through 360 degrees about the longitudinal axis of the model. The surface pressures at the 10 orifices were recorded as the spike was rotated through 360 degrees in increments of 20 degrees. This afforded 180 pressure readings to use for the pressure integration. Pressure distributions were measured with zero spike deflection and with spike deflection angles measured from the centerline of the model of 48', 2^{o} 30', 4^{o} 58' and 7^{o} 15'.

The lift and drag were obtained by an integration of the measured pressure distribution over the model surface. Base pressures were not considered in the computations. The forces which were obtained from the pressure integration are plotted in the figure.

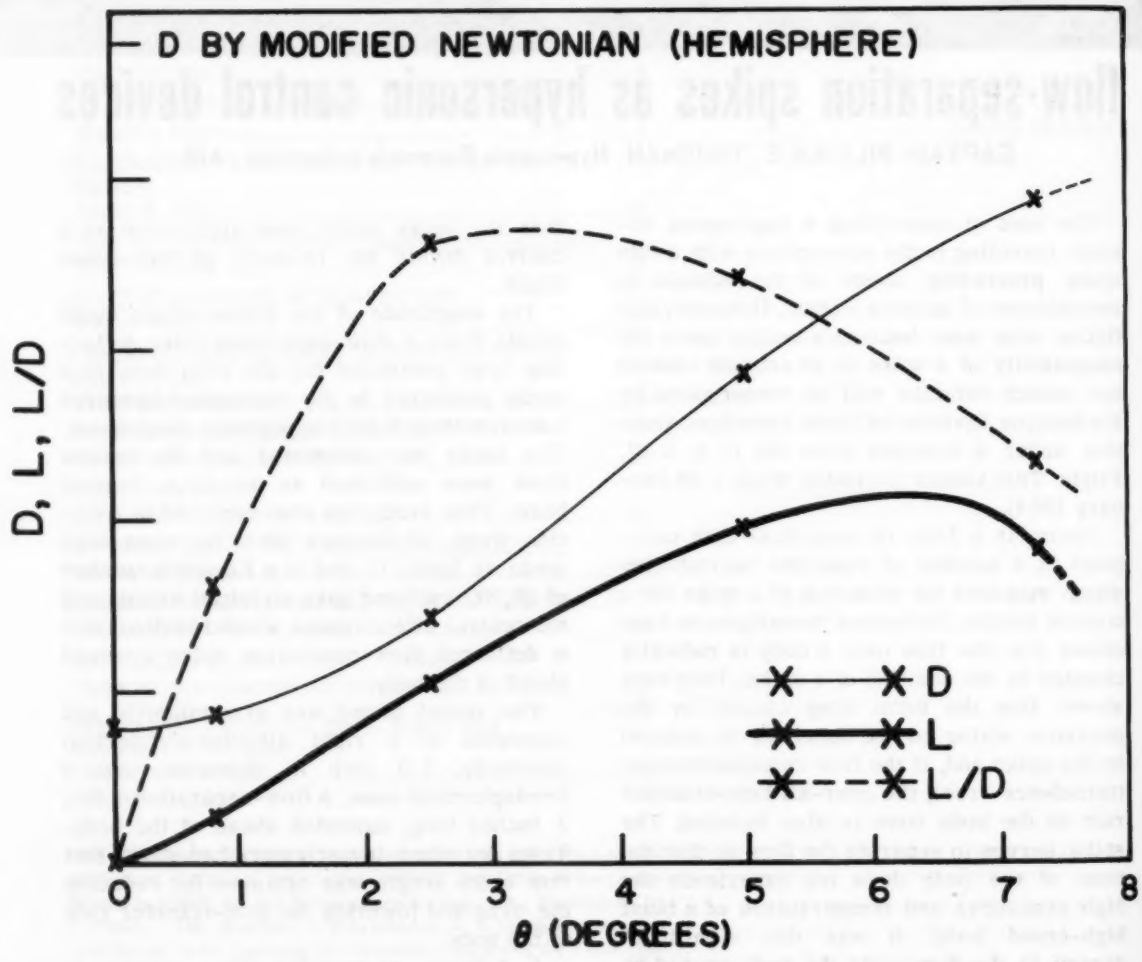


FIGURE - LIFT, DRAG, AND L/D VERSUS SPIKE DEFLECTION ANGLE

The addition of a straight spike reduced the bodies' drag by about 84 per cent. As the spike was deflected from the centerline (figure), the value of the drag increased rapidly. At 7 1/4 degrees of spike deflection, the largest spike deflection investigated, the pressure drag was about 81 per cent of the pressure drag for a hemisphere without a spike.

The deflected spike produced lift (figure) that attained a maximum value near six degrees of spike deflection. It is important to note that lift of the same order of magnitude as the large drag of a high-speed body can be generated by a small spike deflection.

The curve of the lift divided by drag (an important aerodynamic coefficient) is also plotted in the figure. The lift over drag reaches a maximum at about 3.3 degrees of spike deflection and then decreases for larger spike deflections. This value of lift over drag is comparable to that achieved by blunt re-entry vehicles presently in use.

The values of the lift and drag that are plotted in the figure do not include the contribution of the spike itself. However, this contribution was computed (approximately) theoretically for all spike deflections tested. The lift from the spike was found to be less than four per cent of the normal force which resulted from the changing pressure distribution over the body. Since this value was small, it was neglected in this study.

A spiked body is not a panacea, and the tests which have been conducted have not solved the formidable problems of preventing rapid ablation at the spike tip and at flow reattachment to the body. These problems must be solved before a spike is used on a high-speed vehicle.

These tests were conducted at one Mach number and one Reynolds number, and the problems of a high-enthalpy Mach-12 flow were not considered. Subject to these restrictions, one may conclude the following:

1. The flow-separation spike can, when deflected, cause a force in the direction of the spike deflection of the same order of magnitude as the drag forces.
2. The maximum lift over drag and the maximum lift which result from the deflected spike occur at small angles of spike deflection barring any unexpected effects at large spike deflection angles. ★

Reference:

Thurman, William E., A Flow-Separation Spike for Hypersonic Control of a Hemisphere-Cylinder, AIAA J. 2, 159-161, 1964.

AIR FORCE RESEARCH RESUMES

VOLUME 4
1963

In March 1964, the fourth in a series of publications describing the OAR research program in detail was published and distributed. This latest edition, Air Force Research Resumes, 1963 was prepared by the Science Information Exchange (SIE) of the Smithsonian Institution under contract with the Air Force Office of Scientific Research. As with the three previous editions, this volume consists of brief resumes describing each contract, grant and in-house research effort conducted or sponsored by OAR.

The approximately 2,100 individual resumes are grouped by subject into 24 chapters. Within each chapter the resumes are arranged alphabetically by name of per-

former. Four indexes are provided to facilitate access to desired information both for the research administrator and for the scientist. In addition to an exhaustive and sophisticated subject index, there is a principal-investigator index, a contractor index (for contractor, grantee or in-house laboratory) and a contract-(and grant-) number index. Finally, three appendixes are provided. Appendix A identifies all of the organization symbols used in the text. Appendix B lists the addresses of all Air Force R&D organizations. Appendix C lists the titles, program elements and responsible organizations for all OAR research projects.

Volume 4 bears a new title and was prepared by a new contractor, SIE. The first three editions, dating back to 1959, were entitled Basic Research Resumes. The new title, Air Force Research Resumes, was chosen to differentiate this publication from similar volumes produced by other Federal agencies; this problem did not exist at the time of the first edition.

The contract with SIE to produce Volume 4 was the result of a natural desire to get the maximum number of birds per stone. SIE is supported by those government agencies having major research and development programs so that it can serve as a clearinghouse for information on research efforts in progress. It has a computer operation to compile, organize and print out management data for the research organizations that provide research funds. It also employs a group of skilled subject analysts who prepare the indexes required to answer detailed subject inquiries in specific scientific areas. It seemed logical, therefore, to use this combination of skills to produce and index the Resumes.

In preparing the Resumes, SIE was assured of receiving complete and up-to-date information on the OAR research program. Since SIE was already using the DD Form 613 (RDT&E Project Card) as its data source (a form used by the military services to document their research and exploratory development projects), it was necessary only to furnish SIE all of the DD Forms 613 prepared by OAR organizations for their FY-1964 budget submissions, describing their current and proposed research programs. To the fullest extent possible, Air Force Research Resumes, 1963 contains a description of every contract, grant or in-house research effort conducted or sponsored by OAR which was active during FY 1963.

The new subject index in this edition of the Resumes is the direct result of experimentation by SIE in the field of subject information retrieval and the creation of comprehensive subject indexes. The result is an index designed to be used both in breadth and depth--highly specific indexing for use by the specialist, and broader generic indexing for use by the research administrator.

The subject index was computer-generated from the terms and phrases chosen by the subject analysts. Each resume was paraphrased by descriptive sentences written by these specialists. Reference points were extracted and selectively permuted to provide as many points of entry to each sentence as possible without excessive redundancy. The permutations in this subject index differ from most conventional indexes in that the permutations of the "key words or phrases" were used to create modifiers, qualifiers and generic descendents in a hierarchical scheme. The result of this mechanized approach is a comprehensive index which is unique in appearance.

To quote its foreword, "The purpose of Air Force Research Resumes, 1963 is to provide those who conduct, administer or utilize research with a complete and concise reference to the research currently supported by the OAR and to the people performing the research." Government agencies and qualified Department of Defense contractors should obtain copies of the Resumes from the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. The AD number is 431 950. Copies may also be purchased by the general public from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C. 20230.

NONLINEAR VIBRATIONS

MAJOR BERNARD S. MORGAN, JR.
Directorate of Mathematical Sciences, AFOSR

Nonlinear vibrations occur in many physical systems. However, the engineering solution, often used in design, of the mathematical description of such physical systems does not include the true effects of nonlinear vibrations because of linearization of the mathematical description. For many systems no harm results. One specific example where harm does result was found recently in the design of small lightweight reciprocating aircraft engines.

Such engines incorporate centrifugal-pendulum vibration absorbers to minimize torsional vibration of the crankshaft assembly. These are pendulums suspended from the rotating crankwebs and tuned to the harmful frequencies of vibration. In order to increase the power/weight ratio of the engines, their mean effective pressure has been steadily increased and their weight decreased over the years. Increasing the mean effective pressure increases the amplitudes of the torques which excite vibration, so that it increases the amplitude of motion of the pendulum absorbers. Reducing the weight of the pendulums also increases their amplitude. Recently, an engine was designed using the linear theory with pendulums calculated to swing through about 45 degrees. On test it was found that the vibration absorbers were not functioning adequately. On dismantling the engine, they were seen to have been vibrating through a much larger angle than expected, damaging the stops set at 75 degrees amplitude. The problem thus arose: what was wrong with the vibration-absorber design, and what could be done to correct it?

The solution to such a problem was obtained in the course of a research program supported by the Applied Mathematics Division, Directorate of Mathematical Sciences, AFOSR. This program AFOSR 154-63, with Professor J. P. Den Hartog and D. E. Newland of MIT, consists of research in the general field of nonlinear systems, and has included the investigation of the steady-state response of finite-degree-of-freedom systems, in particular those with nonlinear elastic and damping characteristics, to harmonic or nonharmonic excitation. The latter investigation describes the general problem of which the design of centrifugal-pendulum vibration absorbers is a specific example.

The portion of the program applicable to the design problem discussed is the Ph D thesis of Professor Newland (1) and a paper by him (2). The thesis includes a comparative study of methods for the analysis of nonlinear vibrations. It is principally concerned with forced vibrations, and is restricted to lumped parameter systems. The conclusions reached are that, with one exception, all the methods for the analysis of steady-state nonlinear oscillations considered are closely related to Galerkin's method. The collocation, energy, and Ritz minimizing methods differ only in the choice of weighting functions. The first iteration of Duffing's method can be regarded as a special case of Galerkin. The first approximation of Krylov and Bogoliubov is equivalent to the Galerkin method with the approximate solution $\tilde{x} = a \cos vt + b \sin vt$ and weighting functions cos vt and sin vt. As often only one iteration of Duffing or one approximation of Krylov-Bogoliubov will be computationally feasible, the difference between the methods lies only in the choice of an approximate solution and then of the Galerkin weighting functions. The paper presents the application of the results of the thesis to the specific problem of the large-amplitude motion of centrifugal-pendulum vibration absorbers.

Future research will continue on the mathematical aspects of nonlinear analysis to include stability problems in unsymmetrical rotating bodies and rotating bodies containing fluids. ★

REFERENCES:

1. *Newland, D. E., "Nonlinear Vibrations: A Comparative Study with applications to Centrifugal-Pendulum Vibration Absorbers," Ph D Thesis, Massachusetts Institute of Technology, 1963.*
2. *Newland, D. E., "Nonlinear Aspects of the Performance of Centrifugal-Pendulum Vibration Absorbers," ASME paper 63-WA-275. (To be published in an ASME Journal.)*

a different kind of
EXTRAGALACTIC TELESCOPE

RAY R. HEER, JR.
Directorate of Physical Sciences, AFOSR

Professor C.B.A. McCusker of the University of Sydney, NSW, Australia, offers a unique way to study the flux, energy spectrum, composition and arrival direction of cosmic particles which have energies greater tha 10^{18} ev. There is no known way to detect a primary particle in this energy range in the primary state. The primary must be detected through the shower of secondary particles which is created when the primary interacts with particles at the top of the atmosphere. This, in itself, makes the experiment unique since this is an experiment about space which can best be done at the bottom of the atmosphere rather than out in space.

It has been experimentally established that, from about 10^{14} ev up to about 10^{18} ev, the number of shower particles is proportional to the energy of the primary. The proportionality constant is 2×10^9 ev/particle. For example, if a shower had 4×10^7 particles, the energy of the initiating primary would have been about 8×10^{16} ev. There is no reason to suppose that this proportionality does not hold in the region of higher energy which is of interest here. Then, to detect the primary and be able to estimate its energy, one must have an array which is large enough to measure its size.

The largest arrays in existence cover several square kilometers and have detected showers which come from primaries with energy near 2×10^{19} ev. But there is no evidence yet that the upper energy limit has been reached or even approached. That is to say, the slope of the graph of Number of Particles of a Given Energy vs Energy shows no sharp break. All previous experiments have been linked to a central data-collecting station by radio or by electric cable. As arrays have grown larger (as they must, to detect higher energy), the accuracy of arrival-direction data has decreased. It would be impossible to incorporate any reasonable accuracy in a measurement from an array which is 10 km or more across, which uses this method. The difficulty arises from the fact that the velocity of propagation of electromagnetic waves is a constant, and the velocity of cable transmission can, at best, only approach this.

This experiment will make use of 100 liquid scintillators (detectors) arranged in a square grid of 10 rows of 10 detectors each, with each detector 1 kilometer from its nearest neighbors. The detection area is 100 square kilometers. Each scintillator is $7m^2$ and will be buried under 2m of earth. Burying the detectors will permit inexpensive temperature control (scintillator response is a function of temperature), reduce fire hazard, and screen out the soft (electron) component while permitting the penetrating component to reach the detectors. At each scintillator there will be a tape recorder which will record the time and intensity of events as detected.

The arrival time must be measured and recorded to an accuracy of about $\pm 40 \times 10^{-9}$ sec (light travels 12 m). This is achieved--and this is the unique part of the experiment, the broadcast of one signal rather than the reception of many--in the following way: one transmitter broadcasts a Master Clock pulse every 1.7×10^{-6} sec. to the tape recorder at each scintillator; also, at each station, there is a small local oscillator with a period of 40×10^{-9} sec which acts as a "vernier" for each master pulse. The time signals and the events will be superimposed on the tape; each tape has storage space for about one week's data. The information is collected from the tape and analyzed in a preprogrammed computer at the University of Sydney. One of the fascinating things about this experiment is the fact that, if it is found desirable to look for particles with energies beyond the scope of this array, it can be extended to much larger areas with no in-

crease in complexity; it will merely require the addition of more detector units.

But why do the experiment? It should be pointed out that, when particles with energy greater than 10^{18} ev traverse a uniform magnetic field of one gamma, the radius of curvature of their path is greater than the thickness of the galactic disc. It follows that such particles almost certainly originated outside our galaxy. From this experiment we may learn where they originated from, where they are accelerated, and by what mechanism. We may learn what the density of cosmic radiation is in intergalactic space. We should certainly be able to determine if cosmic radiation has an upper energy limit or, at least, push the observed limit upward.

electron-density variations in the ionosphere

RICHARD S. ALLEN
Space Physics Laboratory, AFCRL

Stars twinkle, and twinkling is roughly synonymous with scintillation. Radio stars scintillate. In either case, the effect is caused by some irregularity in the atmosphere. The pulsing light of the twinkling visual star is caused by irregularities, turbulences, and inhomogenities in the air through which the light from the star passes. The scintillation of radio stars is caused by irregularities in the electron density of the ionosphere. Scintillation is nothing more than variations in the amplitude of the radio energy from a radio star.

From this, it can be seen that the study of radio-star scintillations can tell us much about variations in electron densities in the ionosphere. Thus, radio astronomers devote much time to the study of radio-star scintillation. At AFCRL, special emphasis is given scintillation studies because of the importance of ionospheric parameters to the design of Air-Force detection, tracking and communications hardware.

Scintillation studies are not limited to radio stars as radio sources. Satellite signals provide perhaps an even better above-the-ionosphere signal source, permitting scintillations in a great variety of latitude regions to be observed. Recent AFCRL studies of satellite-signal scintillations have led to the unsuspected fact that scintillations--and thus ionospheric electron-density irregularities--vary with latitude. The AFCRL study shows that the scintillation index increases with increasing latitude--that is, the variations in signal amplitude are greater as we move away from the equator. This has been confirmed for the northern latitudes, but not as yet for the southern latitudes.

Normal scintillation studies using cosmic radio sources have not been able to measure this effect. Diurnal, seasonal and geomagnetic effects have obscured latitude dependence. The satellite, however, moves so quickly from horizon to horizon that an ionospheric "snapshot" can be taken. Statistical study of many records shows that this effect occurs in both quiet magnetic periods and disturbed magnetic periods. These findings may force the re-examination of previous data on scintillations which have been analyzed under the assumption that latitude played no part in the distribution of electron irregularities.

The basic instrument used by AFCRL in its scintillation studies is its 84-foot radio telescope at Hamilton, Mass. Signals from the Russian satellite, Cosmos I, and the Transit-4A satellite were extensively used in the observations leading to the discovery of latitude dependence on the distribution of scintillations.

allemande left, molecules all

(CHEMICAL CHAIN REACTIONS)

DENTON W. ELLIOTT
Directorate of Chemical Sciences, AFOSR

Nuclear chain reactions have been in the public eye for a number of years, and have inspired ingenious instructors to devise spectacular illustrations involving interlocking mousetraps, match books, ping-pong balls, etc. Chemical (as distinguished from nuclear) chain reactions have also been known for years. They are particularly significant in gas-phase and high-energy reactions, many of which involve "free radicals," reactive species containing unpaired electrons. Recently, a quite different and potentially important class of "chain" reactions has been discovered by Professor Dale Margerum working with AFOSR support at Purdue University. The prototype of this class of reaction is

$$NiT^{+2} + CuY^{-2} \longrightarrow CuT^{+2} + NiY^{-2}$$

where T and Y are organic "Chelating" agents. T is triethylenetetramine, the formula for which is $H_2N(CH_2CH_2NH)_2\ CH_2CH_2NH_2$; this is represented as N-N-N-N and is called trien. Y is ethylenediaminetetraacetic acid, the formula for which is $(HOOCCH_2)_2 NCH_2CH_2N(CH_2COOH)_2$. This is represented as $A_2N\text{-}NA_2$ and is called EDTA. The reaction, unlike previously described chain reactions, occurs in aqueous solution and does not involve free radicals.

Dr. Margerum has published (J. Am. Chem. Soc. 85, 297, 1963) convincing evidence that the reaction proceeds through the following mechanism:

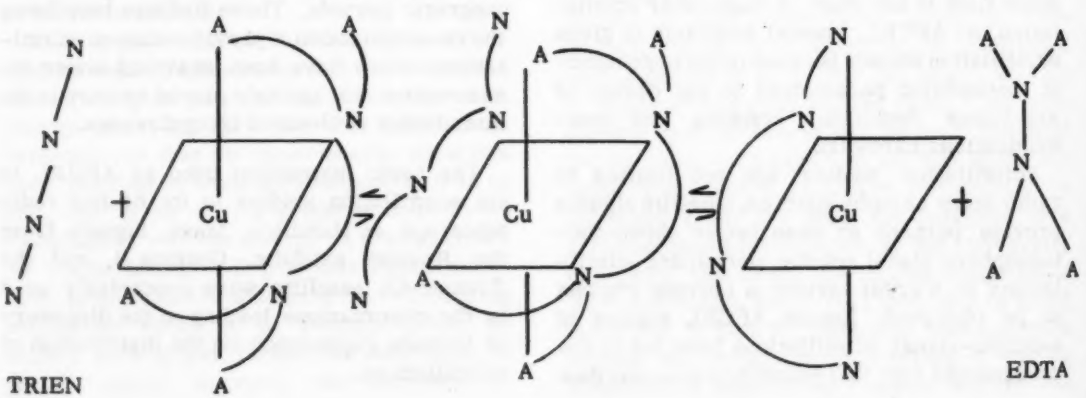
A) $NiT \rightleftharpoons Ni + T$ (slow-initiating)

B) $T + CuY \rightleftharpoons CuT + Y$ (rapid-propagating)

C) $Y + NiT \longrightarrow NiY + T$ (rapid-propagating)

D) $Y + Ni \longrightarrow NiY$ — (terminating)

Step B is believed to occur through a mechanism which may be pictorially represented as follows:



The linear T molecule wraps itself "around" the Cu atom displacing a Y molecule-ion which, in turn, wraps itself around a Ni ion, thereby squeezing out a T molecule. This T molecule will start the process again once it meets a CuY molecule ion.

The repetitive nature of this process makes the term, "chain reaction," applicable to the sequence. Most chain reactions have "chain-branding" steps in which one reactive particle generates several. This type of step is absent here, so that some hesitate to apply the term to this type of reaction. Other names for the reaction might also be conceived. The wrap-around feature suggests "the Yo-Yo reaction" (cf Duncan). In the 1880's a constant-momentum device called the "Flying Pendulum" was incorporated into certain clocks (cf Battieson, Smithsonian Institution). This was a weighted string which flew back and forth between two posts, repeatedly winding and unwinding about each in turn. This also has some similarity to the system in question. A closer analogy is the "allemande" movement in square dancing in which partners are changed by "chaining" around the circle.

Whatever "twist" one may assign to these maneuvers, the propagation of the chain depends on the presence of extremely minute traces of the free forms of Y and T. Even a microscopic amount of a foreign ion, which will complex either, will slow or stop the reaction. This property of the system allows its use as an analytical technique for parts-per-billion amounts of metallic species. In view of the burgeoning importance of ultra-pure materials in aerospace technology, this curious reaction may prove to be of exceptional significance. ★

prose of pose & purpose

(AS RELATED TO NONDIFFERENTIAL EQUATIONS)

DR. ROBERT G. POHRER, Directorate of Mathematical Sciences, AFOSR

Mathematics exists to describe, predict and control our physical environment. And so a significant part of mathematical activity concerns itself with the proper matching of mathematical technique to physical problem. When the mathematical technique turns out to be the solution and application of a differential equation, the activity is known as the problem of THE WELL-POSED PROBLEM.

An interesting new paper* of AFOSR investigator M. D. George (U Missouri) seeks to determine completely well-posed problems for nonlinear differential equations. The mathematical framework employed is one of the most dramatic and productive contemporary developments in mathematics, that of formal differential operators, in the style of Hörmander.

Roughly speaking, if L is a differential operator in a Banach space X, the problem of finding a solution of $Lu = f$, $f \in X$, is said to be (completely) well-posed if the range of L is X and if in addition L^{-1} exists and is (completely) continuous. Earlier results of Hörmander and Browder have established sufficient conditions for the existence of well-posed and completely well-posed problems for formal differential operators.

Professor George became interested in the effect of a nonlinear perturbation operator on a completely well-posed problem. He has now established a set of conditions under which a completely well-posed problem for a differential operator L remains completely well-posed for $L + A$, where A is a nonlinear transformation in X. Combining this result with earlier work of Browder, one can now derive conditions guaranteeing the existence of completely well-posed problems for perturbed differential operators, as Professor George has done in his paper. ★

* *George, M. D., "Completely Well-Posed Problems for Nonlinear Differential Equations," Proc. AMS, Feb. '64, pp. 96-100.*

DIRECT MEASUREMENT OF SKIN FRICTION

CAPTAIN ROBERT C. SMITH
Hypersonic Research Laboratory, ARL

At high-supersonic and at hypersonic speeds, skin friction is a major contributor to the drag of slender vehicles. The theory available is not adequate enough to allow one to calculate the skin friction. Therefore, an experimental program which will determine skin friction at hypersonic speeds for various basic aerodynamic shapes would provide some much-needed information. Such an experimental program is underway at the Aerospace Research Laboratories (ARL). This program will determine skin friction for various basic aerodynamic shapes and then investigate the effect that streamwise injection of a gas will have on skin friction. The program will also develop an instrument capable of measuring skin friction in high-speed flow.

Under the assumptions of continuum flow and no slip at the solid surface, the skin friction, τ_0, at any point on a solid surface in a flowing gas is defined by

$$\tau_0 = \left(\mu \frac{\partial u}{\partial y}\right)_{y=0}$$

where μ = coefficient of viscosity
u = velocity component in boundary layer parallel to the surface
y = coordinate normal to surface

This expression is valid for laminar and, because of the existence of a laminar sublayer, for turbulent boundary layers. Experimental methods to measure the skin friction may be grouped into two general types:

(1) Those that determine the components of the right-hand side of the above equation, and

(2) Those that measure skin friction itself or some physical quantity related to it.

In the first type, it is necessary to determine the viscosity and the velocity profile at the surface. Since viscosity is a function of temperature, this may be determined quite easily by use of an accurate thermocouple mounted in the surface. The velocity profile can not as easily be determined accurately. A pitot tube, hot-wire anemometer, or an interferometer can be used; however, all of these methods are subject to many errors.

In principle, direct measurement of local skin friction is very simple. The frictional force is allowed to move a small floating element on the surface in the direction of the flow and against some restoring force. By physically moving the element back to its original position using a calibrated restoring force, it is possible to accurately determine the skin friction. However, there are difficulties and sources of error in this method also. The moving element must be separated from the rest of the body by small gaps. These gaps may cause changes in the pressure and velocity distributions in the immediate vicinity of the plate which will distort the measurements. The force element has to be small with respect to dimensions of the body in order to obtain a true local-friction force. This results in very small friction forces. Thus the force-measuring mechanism must be very sensitive and accurate.

The University of California, Berkeley has, under various Air Force contracts, developed a series of balances. The last in this series was an ultrasensitive force balance capable of measuring a force in the microgram range. In essence, the balance is a one-component beam balance which uses a crossed strip flexure pivot, a Schaevitz linear variable differential transformer for sensing null,

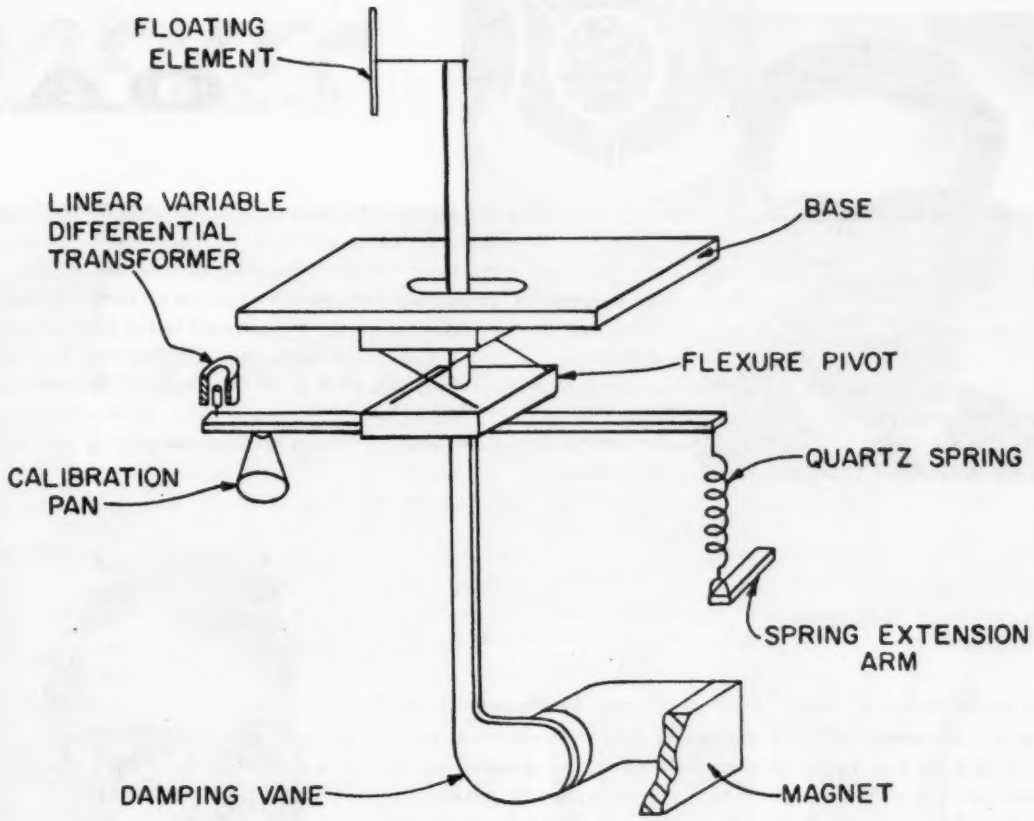


FIG 1. SCHEMATIC DIAGRAM OF BALANCE

and a helical quartz spring for determining the aerodynamic force. Figure 1 is a schematic diagram of the system. The complete balance is housed in a sealed case, and the pressure and temperature are controlled within close limits in order to prevent drifts of the balance components.

The balance described has been used in the low-density Mach-6 wind tunnel at the University of California, Berkeley. Local skin-friction measurements near the leading edge of a flat plate were made using the floating element technique. Although the test results indicated that further model refinement was necessary, data was obtained that suggested that the skin friction was less than that predicted by strong interaction boundary-layer theory.

A program is presently under way at ARL to redesign and modify this balance as necessary so that it may be used in the three-(3) inch hypersonic wind tunnel at ARL. This balance will then be used in conjunction with the previously mentioned in-house study. ★

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First Lieutenant Stephen J. Koob is a scientist with the Fluid Dynamics Facilities Laboratory, ARL. In his current research, he provides assistance in the conductance and evaluation of fluid-dynamics simulation facilities, and prepares contract specifications for facilities and research pertinent to the field of fluid dynamics. He has a B.S. in Aeronautical Engineering from St. Louis University (1960) and an M.S. in Aeronautical Engineering from Rensselaer Polytechnic Institute (1961). In this Review, he writes on "A Magnetic Suspension and Balance System for Wind Tunnels."

Captain Robert C. Smith, a scientist with the Hypersonic Research Laboratory, ARL, is concerned with the investigation of basic problems in hypersonic aerodynamics. At present he is experimenting with the injection of various types of gases into the boundary layer of bodies in hypersonic flight to determine their effect on skin friction and heat transfer. Capt. Smith has a B.S. in Mechanical Engineering and an M.S. in Nuclear Engineering, and is well on his way towards a Ph.D. in Aerospace Engineering. In this Review, he goes into the "Direct Measurement of Skin Friction."

Mr. Richard S. Allen, a physicist with the Space Physics Laboratory, AFCRL, is currently conducting in-house 400-Mcps studies of solar noise and auroral effects. He is task scientist for an investigation of solar disturbances of the F layer, and is assisting in the development of a proposed Air Force research program in radar and radioastronomy using the 84-ft antenna at Sagamore Hill, Mass., the 150-ft radiotelescope at Sagamore Hill and Palo Alto, Calif., and the 1000-ft DoD Ionospheric Research Facility at Arecibo, Puerto Rico. In this issue, Mr. Allen writes on "Electron-Density Variations in the Ionosphere."

PROFILES

Messrs. Arnold S. Orange and Leon A. Ames have written in this Review on "Magnetotelluric Micropulsations." Both are engaged in research at the Microwave Physics Laboratory, AFCRL, Mr. Orange as an electronics engineer, and Mr. Ames as a supervisory research electronics engineer. Mr. Orange (on the left) is currently working on scatter communications and other specialized communications problems. He has B.S. and M.S. degrees in Electrical Engineering from M.I.T. Mr. Ames (on the right) is currently investigating various earth modes of communication. He has a number of publications to his credit, and has done research in microwave relay, data transmission and storage systems, as well as tropospheric and ionospheric propagation.

Captain William E. Thurman is a scientist with the Hypersonic Research Laboratory, ARL. In his current research, he is conducting a preliminary investigation on the use of an aerodynamic spike for control of a hemisphere-cylinder at hypersonic speeds. He has a B.S. from the U.S. Naval Academy (1954) and an M.S. in Aeronautical Engineering from the Air Force Institute of Technology (1962). In this issue of the Review, he describes the use of "Flow-Separation Spikes as Hypersonic Control Devices."

Mr. Louis C. Block (shown on the right) is Chief, Optics and Radiometry Branch, Optical Physics Laboratory, AFCRL. He is currently responsible for the technical operation and coordination of all programs being carried on within his branch. He is a former associate professor of physics, Lowell Technological Institute, and has taught graduate and advanced courses in spectroscopy, atomic physics, advanced optics and nuclear physics. He has a number of publications to his credit. In this issue of the Review, he writes on a "Laser Plasma Probe." Shown (left) in the photo with Mr. Block is a local contractor.

a magnetic suspension and balance system for wind tunnels

1st Lt STEPHEN J. KOOB
Fluid Dynamics Facilities Laboratory, ARL

For those engineers who have tried to duplicate flight conditions in a wind tunnel, the effects of the model-supporting system have always posed a problem. An obvious solution is to magnetically suspend the model in the air stream and thus more truly simulate free flight while keeping the model stationary and easily observable in the laboratory.

References 1 and 2 provide a bibliography of literature on the magnetic suspension of wind-tunnel models and indicate that the first working system was completed in 1955 at ONERA in France. Subsequently, the Massachusetts Institute of Technology became interested in the magnetic suspension system and, after defining the desired capabilities of such a system, concluded that the French system was not entirely suitable for their purpose.

As proposed by MIT, the system consisted of 5 electromagnets geometrically located as shown in Fig. 1. Coils No. 1 and No. 2 serve

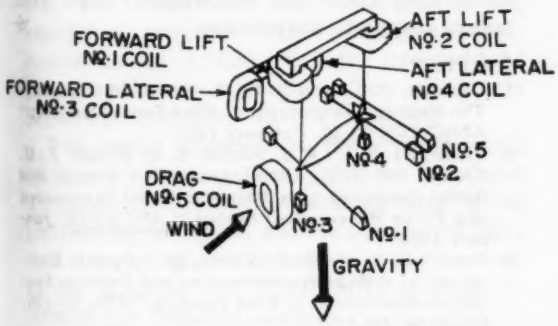

Figure 1. Magnet Configuration Showing Model and Optical Position Sensors

to support the model and magnetize the soft iron cylindrical core which is inserted in the nonmagnetic model. These lift coils must always produce a force against the natural bias of gravity. However, the lateral coils, Nos. 3 and 4, must be biased in one direction such that their current flow be of constant direction. This is accomplished by winding two coils on each leg of the lateral magnet core and applying a constant current to one coil of each leg. The drag coil, No. 5, is an air core solenoid for which the aerodynamic model drag provides a natural loading in the downstream direction. In principle, the electromagnet control signal is obtained by passing a collimated light beam over the model and focusing the beam on a photocell. As the model moves in the light beam, more or less light is cut off from the detector whose output is used as the driving signal to the electromagnet's power supply. By using a suitable control system and stabilization network, the model is positioned and held in the air stream. In Figure 1 the optical paths are numbered corresponding to the magnets which they control. A block diagram of the drag system is shown in Figure 2.

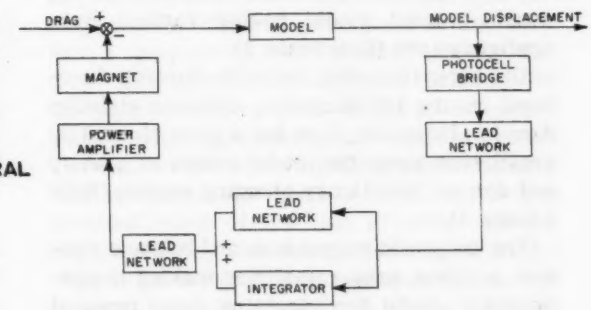

Figure 2. Drag System Block Diagram

Applying these principles, MIT, under the sponsorship of the Aerospace Research Laboratories and with Dr. Eugene E. Covert as principal investigator, has developed a magnetic suspension system for use in the 4" x 4", Mach 4.8, Naval Supersonic Laboratory wind tunnel at MIT. The system is designed to support a 5-ounce model under continuous

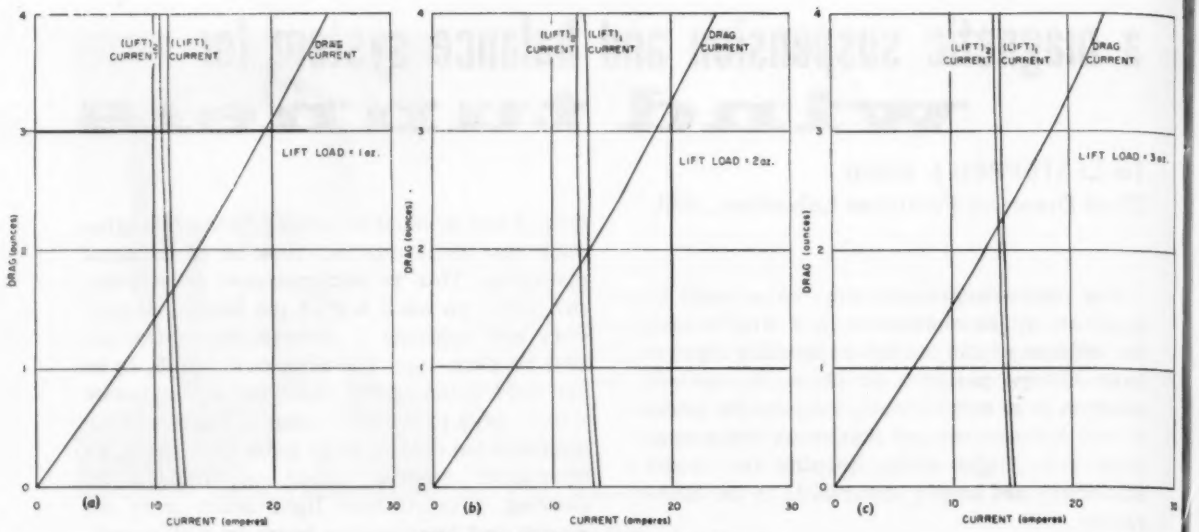

Figure 3. Typical Calibration Curves

wind-tunnel operating conditions and requires no additional support either when flow is initiated or when the tunnel goes out of flow. MIT's work is reported in References 2, 3 and 4.

From a calibration of loading versus coil currents (Figure 3) and the appropriate equations, aerodynamic force and moment data have been obtained for an axisymmetric double-pointed model having various base configurations (Reference 3).

By superimposing suitable forcing functions on the lift magnets, dynamic stability data is obtainable, both for a pure sinusoidal oscillation about the model center of gravity and for an oscillatory plunging motion (Reference 3).

The magnetic suspension and balance system exhibits unique qualities making it particularly useful for obtaining three types of data: force and moment data on bodies for which sting interference may be appreciable; wake studies, for which even thin-wire supports have been found to have a serious effect (Reference 5); and dynamic stability data, on which the character of the wake as influenced by the model support can have a definite effect, particularly for slender bodies (Reference 6).

The system is capable of controlling 5 degrees of freedom, and efforts are being made for the inclusion of roll control, which poses unusual interaction problems. Work is also being done to improve the over-all accuracy and repeatability of position-controlling equipment and the force-and-moment-indicating system.

The future for magnetic suspension and balance systems looks very bright. Since the MIT system reached operational status, interest has been renewed, and other universities and research laboratories are designing, constructing, installing and utilizing similar systems to study problem areas which they could not realistically cope with before magnetic suspension. ★

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MAGNETOTELLURIC MICROPULSATIONS

ARNOLD S. ORANGE AND LEON A. AMES
Microwave Physics Laboratory, AFCRL

If you drive two iron stakes into the ground and connect the ends to an appropriate recorder, you can detect electric-field fluctuations of the earth. In the US, you wouldn't need a very sensitive detector to pick up the very strong 60-cycle frequency of the nation's electrical-power system. But with extremely sensitive equipment and a filter to reject the 60-cycle fluctuations, you could then detect an ultralow frequency known as magnetotelluric micropulsations.

These pulsations can be detected at frequencies below one cycle per second. Their origin is uncertain and subject to conflicting interpretations. Those who have offered explanations seem to be agreed on one point: although the energy input probably originates from outside the immediate earth environment, interaction between this outside energy and the earth's magnetic field, or the ionosphere, results in the particular frequencies that are detected.

During the past year, AFCRL has learned much about magnetotelluric micropulsations largely because of excellent data derived from a three-station detection network. These data have been subjected to IBM-7090 analysis. The results of this experimental and analytical program have recently been published in an AFCRL report, "Analysis of Magnetotelluric Micropulsations at Widely Separated Stations," (AFCRL-64-10).

The three stations of the network were located in Austin, Texas, Puerto Rico, and Trinidad. The first two were operated by the University of Texas, and the third by AFCRL. The longest path-distance between any two of the stations was 2,700 miles between the Austin and Trinidad stations.

Signals may be detected at the earth's surface as either magnetic or electric-field variations. The AFCRL study was concerned with the latter, and principally with a type of oscillation called pc-oscillation in the frequency range from about .01 to .25 cps. It consists of a quasi-sinusoidal wave form with a period between 10 and 40 seconds. The oscillations occur principally during daylight hours and may last from a few minutes to several hours.

Because of extremely low signal levels, the sensing probes had to be carefully designed. Simple devices such as iron stakes driven into the ground or buried lead plates are insufficient. The detectors used by AFCRL consisted of a saturated solution of cadmium chloride placed in a small, partially buried glass crucible. Protruding through a rubber stopper at the mouth of the crucible was a cadmium rod, with one end immersed in the solution, and the other end leading to a recorder. The bottom of the crucible consisted of a porous ceramic wafer, permitting good electrical contact between the solution and the surrounding earth.

Many ideas concerning the origin of micropulsations have been offered. One interpretation of these pulsations is that they are a phenomenon of the local ionosphere. Other researchers have placed the origin in the high atmosphere. Still others have hypothesized the pulsations as magnetohydrodynamic waves traveling along a geomagnetic line of force. The wave is reflected at the meeting point of the line of force and the earth's surface. Several more complex mechanisms have been postulated. Most hypotheses involve latitude dependence of the oscillations.

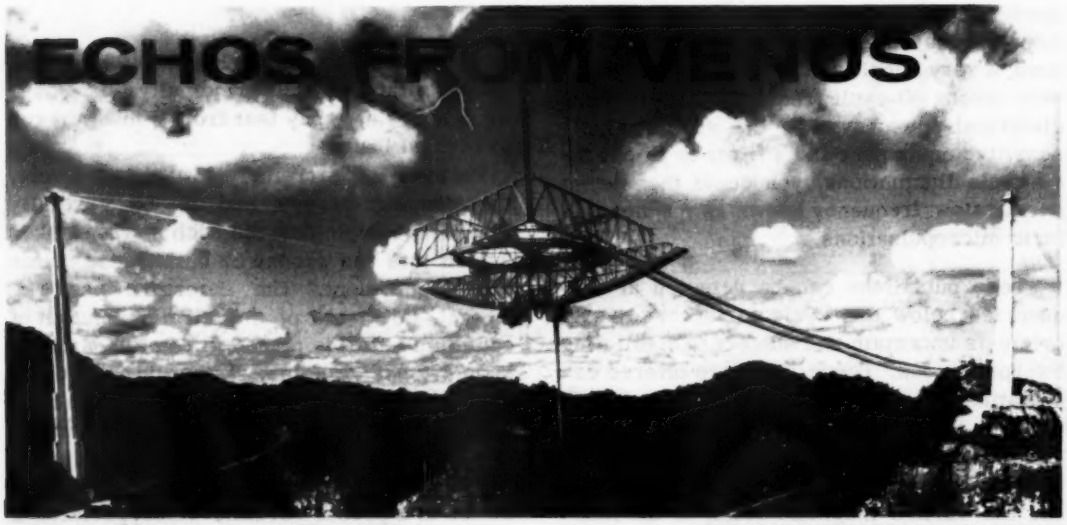
The AFCRL study does not suggest a mechanism for the magnetotelluric micropulsations other than a generalized pulsation of the magnetosphere (a region extending to several earth radii). But it does suggest that previous hypotheses involving latitude dependence or location effects may be in error.

This suggestion grows out of AFCRL's rigorous coherency and spectral analysis. The analysis shows coherency as high as .8

for stations separated by more than 2,000 miles. No difference in the power spectra was observed. Thus, the oscillation appears to occur at the different stations simultaneously over great distances. In all likelihood, the same source is responsible for the same oscillations at widely separated points.

The analysis uncovered three regularly spaced spectral peaks which had not previously been reported. These peaks are found at .125, .175 and .225 cps. ★

ECHOS FROM VENUS



DR. MARSHALL C. HARRINGTON
Directorate of Physical Sciences, AFOSR

ARECIBO RADIO-RADAR TELESCOPE
OFFICIAL PHOTO - HQ OAR ● USAF

The planet, Venus, was detected by the powerful radar beam of the Arecibo Ionospheric Observatory on 15 February 1964. On that date, the planet was at a distance of about 266 million miles from the earth, or more than 4 times the distance at which the planet was first seen by radar in 1961. Three American groups (Millstone Radar Observatory Staff, W. K. Victor and R. Stevens, and I. Maron), a British group (J. H. Thomson), and a Russian group (V. A. Kotel'nikov), completed their first observations at about the same time. When Venus has approached the earth closely again in June of this year, its signal will then appear nearly 1,000 times stronger.

The Arecibo Ionospheric Observatory was dedicated on 1 November 1963 and, since that time, tests of its capabilities have borne out the expectations of the designers of this, the world's most powerful radio-radar telescope. The antenna is in the form of a portion of a sphere 1,000 feet across. The peak power is 2½ megawatts, and frequency is 430 megacycles per second. (A description of the instrument appeared in the 2 December 1963 issue of the OAR Research Review.)

The facility is operated by Cornell University with funds provided by the Advanced Research Projects Agency and monitored by the Air Force Office of Scientific Research, Office of Aerospace Research.

Observation of Venus by the instrument first became possible near the middle of February as the planet moved into the region of the sky accessible to the antenna. Observations will continue until next November in order to ascertain as accurately as possible the motion of the planet over a large fraction of its orbit. At the time of closest approach next June, the radar echo from Venus should be strong enough to permit a resolution of some of the puzzling questions concerning the nature of the surface of the planet and its rate of rotation. ★

Schedule of Scientific Symposia

11-14 May 1964 — SYMPOSIUM ON APPLIED MATHEMATICS & MECHANICS IN HONOR OF THEODORE VON KARMAN, Washington, D.C. Cosponsors: Air Force Office of Scientific Research (AFOSR) and Society for Industrial & Applied Mathematics. For information contact Maj B. S. Morgan, Jr., AFOSR (SRMA), Tel: OX 6-1302. UNCLASSIFIED

5-13 June 1964 — SYMPOSIUM ON QUANTITATIVE BIOLOGY, at Cold Spring Harbor, NY. Cosponsors: AFOSR and Cold Spring Harbor Laboratory of Quantitative Biology. For information contact Capt B. D. Stollar, AFOSR (SRLA), Tel: OXford 6-4181. UNCLASSIFIED

8-10 June 1964 — FOURTEENTH MRI SERIES SYMPOSIUM, "QUASI OPTICS," at Statler Hilton Hotel, New York, NY. Cosponsors: AFOSR, Army Research Office (ARO), Office of Naval Research (ONR). For information contact Lt Col W. C. Athas, AFOSR (SREE), Tel: OXford 6-3671. UNCLASSIFIED

22-27 June 1964 — INTERNATIONAL BIOPHYSICS MEETING, at Paris, France. Cosponsors: AFOSR, International Organization for Pure & Applied Biophysics, and National Academy of Sciences. For information contact Capt B. D. Stollar, AFOSR (SRLA), Tel: OXford 6-4181. UNCLASSIFIED

22-24 June 1964 — INTERNATIONAL CONFERENCE ON PHOTOSENSITIZATION IN SOLIDS, at Illinois Institute of Technology, Chicago, Ill. Cosponsors: Air Force Cambridge Research Laboratories (AFCRL), ONR, Space Physics Laboratory, and Illinois Institute of Technology. For information contact T. K. Mukherjee, AFCRL (CRFE), Tel: Area Code 617, CRestview 4-6100, Ext 3227. UNCLASSIFIED. Attendance by invitation only.

6-9 July 1964 — LEARNING & ASSOCIATED PHENOMENA IN INVERTEBRATES, at Cambridge University, Cambridge, England. Cosponsors: AFOSR, ONR, National Science Foundation (NSF), American Society of Zoologists, and British Association for the Study of Animal Behavior. For information contact Dr. R. V. Brown, AFOSR (SRLA), Tel: OXford 6-4181. UNCLASSIFIED

6-11 July 1964 — CONCENTRATED VORTEX MOTIONS IN FLUIDS, at University of Michigan, Ann Arbor, Mich. Cosponsors: AFOSR, ONR, NSF, National Aeronautics and Space Administration (NASA), and International Union of Theoretical and Applied Mechanics. For information contact Maj W. B. Terrell, AFOSR (SREM), Tel: OXford 6-3425. UNCLASSIFIED. Attendance by invitation only.

6-31 July 1964 — 1964 SUMMER RESEARCH INSTITUTE ON ALGEBRAIC GEOMETRY, at Whitney Estate, Woods Hole, Mass. Cosponsors: AFOSR, NSF, American Mathematical Society (AMS), North Atlantic Treaty Organization. For information contact Dr. R. G. Pohrer, AFOSR (SRMM), Tel: OXford 6-5248. UNCLASSIFIED. Attendance by invitation only.

14-17 July 1964 — FOURTH INTERNATIONAL SYMPOSIUM ON RAREFIED GAS DYNAMICS, at University of Toronto, Toronto, Canada. Cosponsors: AFOSR, ONR, NASA, and University of Toronto. For information contact Maj W. B. Terrell, AFOSR (SREM), Tel: OXford 6-3425. UNCLASSIFIED

20-24 July 1964 — THE INTERNATIONAL CONGRESS ON SEMICONDUCTOR PHYSICS, at Paris, France. Cosponsors: AFOSR, NSF, ONR, and International Union of Pure & Applied Physics. For information contact Capt R. A. Schalow, AFOSR (SRPS), Tel: OXford 6-1161. UNCLASSIFIED

17-22 August 1964 — INTERNATIONAL ASTRONOMICAL UNION SYMPOSIUM NO. 25, at Thessaloniki, Greece. Cosponsors: AFOSR, International Astronomical Union, Government of Greece, and University of Thessaloniki. For information contact Maj B. R. Agins, AFOSR (SRMA), Tel: OXford 6-1302. UNCLASSIFIED. Attendance by invitation only.

Sept. or Oct. 1964 — CONFERENCE ON HIGH-ALTITUDE PLASTIC BALLOONS, at Boston, Mass. Sponsor: AFCRL. For information contact T. W. Kelly, AFCRL (CREB), Tel: Ext. 3013. UNCLASSIFIED

approximation of the DIRAC DENSITY MATRIX

DR. HERBERT PAYNE
General Physics Research Laboratory, ARL

That portion of modern physics which embraces atomic, molecular, and solid-state phenomena differs from others--notably, nuclear and elementary-particle physics--in that there exists a fundamental theory which is presumed capable, at least in principle, of fully accounting for such phenomena. However, when one attempts to apply this theory in a straightforward fashion, the mathematical problem which results, under typical circumstances, is difficult in the extreme. In only the simplest cases has anything approaching an exact solution been attained.

Thus, the challenge to the theoretician working in this area becomes one of devising models sufficiently close to actuality as to predict properties under examination within prescribed tolerances with respect to their measured values, but sufficiently removed therefrom as to render the calculation of these quantities tractable.

Even if exact solutions were feasible by means of large-scale computers, such models would conceivably serve a purpose in providing the research worker with a relatively simple picture in place of extensive tables of numerical data. As an example, the development of the transistor was based upon such a model, inexact but highly illuminating.

According to this fundamental theory, the movements of the electrons comprising a typical system are described through a single wave equation involving a number of variables equal to three times the number of electrons, or to the degrees of freedom in the system. Thus, except for the simplest system, i.e., the hydrogen atom with its single electron, an analytical solution of this (second-order differential) equation is hardly to be expected. Indeed, for molecules or the heavier atoms, the solution becomes so complex as to virtually preclude its numerical expression.

A commonly employed simplification is the one-particle approximation. This treats the electrons as though they moved independently of one another. The (Coulomb) forces that they actually exert upon each other are handled, as well as the approximation permits, through a potential energy, a function of position, which is assigned to the system, i.e., applying in the same way to each electron therein. The effect is to reduce the solution of the system wave equation to an expression composed in a simple way of the solutions of a set of wave equations, one for each electron. Hence, each of the latter solutions contains only three variables, making it correspondingly easier to obtain.

The state of a given electron is defined by the solution, or wave function, of the reduced wave equation corresponding to it. The associated eigenvalue, which permits the solution to satisfy the system's boundary conditions, is related to the energy characterizing that state. Since the Pauli exclusion principle permits only one electron per state, the ground state for the system, i.e., the state of lowest energy, is realized when the infinity of possible electronic states are occupied in order of increasing electronic energies beginning with the minimum.

All of the properties of such a system in the ground state are determinable from a single function, the Dirac density matrix, which may be expressed in terms of the electronic wave functions. However, an alternative definition of the density matrix, without recourse to the individual wave functions, is known. This suggests the possibility of obtaining the density matrix directly from the potential energy of the system and the maximum electronic energy. Such a procedure would bypass the solving of the individual wave equations, or the particle-by-particle examination of the system, a process which becomes extremely cumbersome for a large number of electrons. Thus, for studying the properties of the system itself, when that

system is in the ground state, a further simplification within the realm of the one-particle model seems worthy of investigation.

A crudely approximate expression for the density matrix along these lines is well known. It serves as the basis of the Fermi-Thomas statistical model of the atom. Unfortunately, its utter simplicity is achieved at too great a sacrifice in the accuracy of its predicted values for many important physical properties.

For this reason, much attention has been devoted of late to a search for an improved formula, relating the density matrix to the potential energy and the maximum electronic energy. Some success in this venture has been achieved at ARL.

An expression which is accurate when the gradient of the potential energy is constant--in contrast to the Fermi-Thomas formula, which is accurate when the potential gradient vanishes--has been developed. It has the additional advantage over the latter model in that it is properly characterized where the potential energy exceeds the maximum electronic energy. Wave mechanics, unlike classical mechanics, permits a particle to exist where its potential energy is greater than its total energy. The Fermi-Thomas model, dependent upon a classical argument, fails in this nonclassical region. ★

OAR OFFICER-SCIENTISTS JUDGE SCIENCE FAIR

OFFICIAL PHOTO - HQ OAR ● USAF

OAR has furnished judging teams for four major regional Youth Science Fairs in the greater Washington, D. C. area. Shown above are (left to right) Lt. Colonel Ernest J. Davis, Jr., Colonel John R. Fowler, and Lt. Colonel James V. Powers of Hq OAR, and Lt. Colonel Robert E. Robards, Hq USAF, viewing a student's science fair project on "Demineralization of Saline Water by Electrodialysis."

Biological Insights Through the Isolated Retina

CAPTAIN B. D. STOLLAR
Directorate of Life Sciences, AFOSR

The retina is the light-sensitive structure at the back of the eye. It is a versatile structure, for it is able to: 1) receive and respond to stimulation by light; 2) transduce the light energy to an electrical signal, with great amplification; and 3) begin the extraction and processing of useful information received from the light stimulation. This information is then sent to the brain for further analysis and abstraction. The retina contains specialized photoreceptor units, but also includes nerve elements of the same nature and origin as the grey matter of the brain. It is important to note this feature, for studies of the relatively easily accessible retina are thus relevant to questions about the function of more centrally located brain tissue.

A further remarkable feature of the retina is that it is almost uniquely suited to isolation from the intact eye and to being maintained outside the body. In the eye, it exists as an extremely thin membrane, and is readily separated from the tissues on either side of it. At the Massachusetts General Hospital, Dr. A. Ames III, an AFOSR grantee, has developed the techniques for separating the rabbit retina and keeping it alive outside the body. By several criteria, the separated retina remains in a functional state very similar to its normal state in the body.

Dr. Ames has developed ways to position the isolated retina as a membrane separating two halves of an incubation chamber. Under these conditions, one can approach the study of basic mechanisms of the function of biological membranes. One can readily measure electrical-potential gradients and the transport of nutrients and ions across the membrane.

In some of these studies, it has been possible to measure how the isolated retina functions when deprived of oxygen and nutrients such as glucose. The brain-like nerve elements of the retina are found to be more sensitive to deprivation than the specialized photoreceptors. The harmful effects of deprivation appear to occur in two phases. Similarly, the remarkable recovery after restoration of normal condition occurs in two phases. Recovery after a marked functional loss due to temporary oxygen deprivation is complete, whereas the recovery from a similar degree of functional loss due to glucose deprivation is only partial. This experimental system will allow a deeper examination of what steps lead to irreversible and progressive loss of function, and eventually to death. Access to brain-like tissue in the retina to study this problem is especially important, since the brain is the vital organ which most quickly loses its function in oxygen and nutrient deprivation.

It has also been possible to measure directly the electrical responses of units in the retina to selective stimulation by light. Minute electrodes can be introduced into single "bipolar" cells, which are part of the first-relay network receiving information directly from the photoreceptor units. When a specific area of the retina is illuminated, an electrical signal is received in a single corresponding bipolar cell. The signal received is similar to a part of the more gross signal recorded from a retina in an intact animal. Certain cells respond only at the instant when a light stimulus is turned on; others respond only when the stimulus is turned off. Along with other work on the visual system, including studies by other AFOSR grantees, these experiments show that the retinal cells extract information from changing patterns of light; the analysis mechanism is a dynamic one, leading to useful abstractions. A limited number of types of cell responses are found, and it is hoped that this approach can give new insight into the way these cells interact in visual analysis. Such insight will constitute a development of major importance, for it will provide a highly sophisticated model of how to extract, with very fine discrimination, meaningful information from environmental light patterns. ★

NOCTILUCENT CLOUD-PARTICLE STUDIES

Space Physics Laboratory, AFCRL

In August 1962 AFCRL, in a joint program with NASA, sent a specially designed rocket nose cone through noctilucent clouds to collect samples of noctilucent cloud particles. The examination of these samples uncovered a puzzling feature. About 20 per cent of the microscopic sample traces were ringed by a halo-like structure.

This structure was tentatively explained as resulting from water or ice that had surrounded the particle prior to impact with the collecting surface. The problem with this explanation was that few scientists believed that water vapor in sufficient quantity to collect on the cloud particles would be found at the noctilucent-cloud altitudes. To verify this explanation, AFCRL undertook an effort to simulate the atmospheric processes involved in the impact of the particles on the nitrocellulose collector.

The origin and composition of noctilucent clouds themselves have always been something of a mystery, and it was this which led to the experiment in the first place. The experiments consisted of launching several Nike-Cajun rockets into the sky over Kronogard, Sweden. Noctilucent clouds, observed most often and most vividly in northern latitudes, occur at altitudes of about 250,000 feet, which is about 40 miles higher than the realm of weather. This is above more than 99.9 per cent of the earth's atmosphere. The noctilucent clouds can be seen at night because they reflect sunlight that reaches them from far below the horizon of the observer.

Particle samples were collected on aluminum-coated nitrocellulose films. To make certain that the particles were in fact collected in the visible noctilucent clouds, control rocket flights were made at times when no noctilucent clouds were observed.

The collected particles have been very carefully examined and have been explained as meteoritic particles and/or the residue of burned-out meteors. Why they are most often seen in northern latitudes is still not understood.

In the attempt to simulate the halo effect, particles of various materials were propelled against a substrate with a freon propellant. When an aqueous slurry of submicron nickel particles was propelled by liquid freon against the nitrocellulose, the water in the slurry impacted as ice (the nickel particles served as nuclei) and rings similar to those around the noctilucent particles were observed. The appearance of the ring patterns was also found to be strongly dependent on the relative humidity at the time of, and immediately following impact.

The encouraging results of this first series of experiments have stimulated further study of the interaction of water with nitrocellulose, and have led AFCRL to make additional studies under simulated conditions. For these latter measurements, a test chamber in which the pressure, temperature, relative humidity and particle-impaction velocity can be controlled and measured, has been constructed. Other types of particles and collection surfaces will also be investigated.

These studies were performed by R. A. Skrivanek and R. K. Soberman of AFCRL. ★

AFCRL notes

An Aerobee sounding rocket was launched on 30 March 1964 from the White Sands Missile Range. The purpose of this experiment was to measure the incident solar radiation from 310 to 55 angstroms in the extreme ultraviolet portion of the spectrum under "quiet" solar conditions. The vehicle with its 205-pound pay load attained a zenith of about 152 statute miles. During the ascent, the nose cone was automatically oriented to point its sensing elements at the sun. The nose cone contained a grazing-incidence, photoelectric monochromator. The basic scientific information was telemetered to the ground, and the nose cone was recovered. Results were highly satisfactory. Dr. H. E. Hinteregger is AFCRL's project scientist. Charles W. Chagnon is the field director. (Upper Atmosphere Physics Laboratory)

PRELIMINARY REPORT ON THE 27 MARCH 1964 ALASKAN EARTHQUAKE

MAJOR
HOWARD W. LEAF
Directorate of
Physical Sciences
AFOSR

Dr. Frank Press, Director of the Seismological Laboratory of the California Institute of Technology, following an inspection of the earthquake area, has classified it as one of the major earthquakes of historical times, ranking it with the great Krakatoa explosion and the San Francisco earthquake of 1906. Accompanied by three scientists from Cal Tech, Dr. Press visited and flew over much of the affected area. In a letter report on the trip, Dr. Press indicated that he and his group found evidence of vertical changes in the shore line of from six to ten feet over distances of up to 600 km in length. An earthquake of this size, Dr. Press reported, will have aftershocks for as long as two years after the main event.

To monitor and record these events, the Cal Tech group installed two portable seismic stations, one at Middleton Island and the other at Seward, on either side of what is expected to be the major fault structure, though no surface expression of the fault was found. These stations supplement the U.S. Coast & Geodetic Survey's effort in monitoring the aftershocks. The aftershock investigation is of particular interest and relevance to the research being conducted by the Seismological Laboratory, under AFOSR monitorship, in support of ARPA's Vela-Uniform Program.

Dr. Press stated, in his report, "The structure of the Gulf of Alaska and the Aleutians bears much resemblance to that of Soviet Kamchatka and the Kurile Islands. The pattern of earthquakes is the same, the occurrence of deep sea trenches and profound gravity anomalies is similar. One of the chief problems of monitoring an underground-test-ban treaty concerns the high seismicity of this Soviet territory. If a significant improvement in precision of epicenter location can be made, many suspicious tremors could be eliminated from consideration because of their offshore location. The Alaskan earthquake and its aftershocks will make a good case history of such a seismic area where, under controlled conditions, we can study our capability of precisely locating small earthquakes."

In addition to the above research, several long-range problems will be worked on as the seismic data becomes available, including the interesting problem of the free oscillation of the earth that is induced by an event of this size and instrumentally detected only in the last several years. ★

to our readers

Requests for further information should be directed to the individual or laboratory of origin (except for those from Latin America).

Addresses are as follows:

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Attn: CRI
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AEROSPACE RESEARCH LABORATORIES
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Wright-Patterson Air Force Base, Ohio 45433

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
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OFFICE OF RESEARCH ANALYSES
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Holloman AF Base, New Mexico 88330

Requests for further information from institutions and individuals in Latin America should be addressed to:

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